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TITLE: MODULAR PLASTICS EXTRUSION DIE

[001] This is a Continuation-in-Part of patent application number US-09/514,359, filed 28 February 2000, granted 05 February 2002 as US patent number (not yet known).

Summary of the Invention

[002] This invention relates to co-extrusion dies for extruding multilayer polymer materials into a single tubular form.

BACKGROUND OF THE INVENTION

[003] Many areas of polymer processing require multiple layers of different polymers to be co-extruded into a single tubular form. One example is the blown film process which is used to make most of today's commodity bags and also high barrier food packaging. Although multi-layer packaging can be made from co-extruded flat film, using a tubular form presents fewer sealing operations, results in less trim scrap and is more conducive to certain product shapes.

[004] Tubular forms are used in many applications including the production of multilayer pipe or tubing, pipe coating, wire coating, and the production of multi-layer parisons for blow molding. Tubular parisons are used in making containers of various shapes as annular dies are typically easier to manufacture than dies of other shapes, such as oval or square. Annular co-extrusion dies are commonly used to process high volume commodity resins as well as relatively low volumes of barrier type resins.

[005] Annular co-extrusion dies are generally of one of two arrangements; namely axially fed and radially fed. In either type of arrangement, melt is introduced into an inlet port from where it has to be evenly distributed about the circumference of an annular outlet. Good flow distribution is essential to forming film having layers which are uniform in thickness, appearance and structural integrity. In axially fed co-extrusion dies, melt is fed in a direction parallel to the axis of the tubular form to be extruded.. Each layer is formed between respective die elements which are generally concentrically disposed in a manner analogous to cups of different diameter stacked one within an other. The individual layers are merged upstream in an extrusion passage through which the co-extruded film is discharged.

[006] In radially fed co-extrusion dies, melt distribution blocks are stacked one behind another along a die axis and melt is fed radially relative to the die axis into a respective inlet port in each melt distribution block. The melt distribution blocks distribute the melt about a central mandrel and discharge the melt in an axial direction into an extrusion passage between the melt distribution blocks and the mandrel. Each consecutive melt distribution block applies an overlying melt layer to the melt moving along the extrusion passage.

[007] Axially stacked radially fed co-extrusion dies are advantageous in that it is relatively simple to vary the number of layers by varying the number of "modules" stacked along the die. Furthermore, each level presents a similar area and the levels are more easily thermally isolated than possible with axially fed co-extrusion dies in which heat from one die element is difficult to isolate from adjacent die elements. Even melt distribution is however a much more challenging problem with radially fed co-extrusion dies because of a

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ABSTRACT

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much shorter axial distance being available for melt equalization and the requirement to redirect melt flow from a radial to an axial direction after the melt has been distributed into a thin film.

[008] It is an object of the present invention to provide a radially fed multilayer extrusion die which is effective in providing a uniformly thick film of melt to an extrusion passage.

[009] It is a further object of the present invention to provide a melt distribution block for a radially fed multilayer extrusion die which can accept and combine two different types of melt.

[0010] It is yet a further object of the present invention to provide a melt distribution block for an extrusion die having a matched pair of distribution passages so configured and oriented as to cause an averaging of extruded film thickness by matching high flow areas of one of said pair of passages with lower flow areas of the other of said pair of passages.

## SUMMARY OF THE INVENTION

[0011] A melt distribution block for feeding melt through an extrusion die to an extrusion passage. The melt distribution block has a generally annular body with an inner face extending about the extrusion passage, an outer face radially outward of the inner face and opposite front and rear faces. The front and rear faces each have a series of flow divider channels thereon which extend in a generally radially inward direction from an inlet through a series of flow diverting bifurcations which terminate in a plurality of feed spirals. Each of the feed spirals substantially encircles the inner face and narrows toward a radially inwardly disposed end. The feed spirals on the front and rear faces curve in respectively opposite directions. An inlet port extends into the outer face to fluidly communicate with the inlet of the flow divider channels.

[0012] A melt distribution die has an axially stacked array of melt distribution blocks of the type described above interspersed with separator blocks extending radially about a centrally disposed mandrel. An extrusion passage is defined between the mandrel and the stacked array of melt distribution and separator blocks. The separator blocks cover the flow divider channels to maintain melt flow within the flow divider channels. The separator blocks are spaced apart from the feed spirals to define a generally continuous melt outlet passage extending into the extrusion passage.

[0013] In order to thermally isolate adjacent feed spirals, the separator blocks may be provided with a radially extending insulating zone generally corresponding in location to the feed spirals.

## DESCRIPTION OF DRAWINGS

[0014] Preferred embodiments of the invention are described below with reference to the accompanying drawings in which:

Figure 1 is a perspective view of a melt distribution block according to the present invention;

Figure 2 is a perspective view corresponding to Figure 1 but showing an opposite face of a melt distribution block according to the present invention;

Figure 3 is a top plan view of a melt distribution block according to the present invention;

Figure 4 is a bottom plan view of a melt distribution block according to the present invention;

Figure 5 is a section on line 5 - 5 of Figure 4;

Figure 6 is an axial section through a melt distribution die according to the present invention;

Figure 7 is an axial sectional view illustrating one half of a melt distribution block according to the present

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invention mounted between two separator blocks; and,

Figure 8 is an axial section through a melt distribution die according to an alternate embodiment of the present invention

Fig 9 is a view of a groove face similar to that shown in Fig 1.

Fig 10 is a diagrammatic view showing another grooves layout.

Fig 11 is a diagrammatic view showing a further grooves layout.

Fig 12 is a diagrammatic view showing yet another grooves layout.

Fig 13 is a close-up of a portion of Fig 9.

#### DESCRIPTION OF PREFERRED EMBODIMENTS

[0015] A melt distribution block according to the present invention is generally indicated by reference 10 in the accompanying illustrations. The melt distribution block has a generally annular body 12 with an inner face 14 which, in use, extends about and defines part of an outer surface an extrusion passage 16 in Figures 6 and 7. The melt distribution block 10 has an outer face 18 radially outward of the inner face 14, a front face 20 in Figure 1 and a rear face 22 in Figure 2, opposite the front face 20.

[0016] The front and rear faces, 20 and 22 respectively have a series of flow divider channels 24 extending into their surfaces. The flow divider channels 24 are generally concentrically disposed and define a flow path which extends in a generally radially inward direction from an inlet 26 through a series of flow dividing bifurcations 28.

[0017] Each of the flow dividing bifurcations 28 is located at a juncture of the end of a flow dividing channel 24 and the midpoint of an adjacent, radially inwardly disposed flow dividing channel 24. The direction of melt flow is initially from an inlet 26 into the outermost flow divider channel 24 and then through the flow dividing bifurcations 28 into adjacent radially inwardly disposed flow dividing channels 28. Upon passing through each flow dividing bifurcation 28, which are in effect "T" junctions, melt flow is divided into two generally oppositely directed melt flow paths of similar configuration and therefore similar flow rate.

[0018] The flow dividing channels 24 distribute melt from the inlet 26 evenly about the mold block 10 which is important as a first step in ensuring uniformity of flow from the mold block 10 into the extrusion passage 16 about its circumference.

[0019] The flow dividing channels 28 terminate in four feed spirals 30 which are radially inward of the flow dividing channels 28. Although four feed spirals 30 are illustrated, other numbers may be selected as being more desirable in some applications, keeping in mind however that the number of flow dividing channels 28 would have to be selected accordingly.

[0020] Each feed spiral 30 is "fed" by (ie., fluidly communicates with) two of the flow divider channels 24 at references 31 to obtain as consistent as possible a flow of melt into each of the feed spirals 30 by "averaging" the melt flow between adjacent flow divider channels 28.

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[0021] Each feed spiral 30 substantially encircles the inner face 14 in a loop of diminishing radius and breadth. The feed spirals 30 are basically channels of diminishing width and breadth, the purpose of which is to evenly spread melt over a thin, even layer before it enters the extrusion passage 16. Using a plurality of circumferentially spaced apart feed spirals 30 evens out the flow from each feed spiral. To further even out high and low flow areas, the front and rear faces 20 and 22 have respective feed spirals 30 which curve in opposite directions relative to each other as viewed through the melt distribution block 10.

[0022] It should be noted that although the feed spirals 30 in Figures 1 and 2 appear to curve in a clockwise direction, Figures 1 and 2 depict faces of a melt distribution block 10 which would face away from each other. Accordingly, if either of Figures 1 and 2 is flipped over and viewed against a light, it will become apparent that the curve of the feed spirals 30 when viewed "through" the melt distribution block 10 is reversed from that when viewed on its face. A similar reversal should be notionally taken into account in considering the plan views of Figures 3 and 4.

[0023] As can be seen in Figures 3, 4 and 5, an inlet port 32 extends into the outer face 18 of the melt distribution block 10 and fluidly communicates within the inlets 26 of the flow divider channels 24. As illustrated, the inlet port 32 feeds the inlets 26 on the front face 20 and rear face 22 of the melt distribution block 10. Alternatively, as suggested by dashed line 34 in Figure 5, the inlet port 32 may be divided into separate ports, 32a and 32b respectively, to feed different types of melt to the front and rear faces 20 and 22 respectively.

[0024] A melt distribution die according to another aspect of the present invention is generally indicated by reference 40 in Figure 6. A segment of a melt distribution die 40 is shown in larger scale in Figure 7. The melt distribution die 40 includes an axially stacked array of melt distribution blocks 10 as described above interspersed with separator blocks 42, extending about a central mandrel 44. The extrusion passage 16 is defined between the separator blocks 42, melt distribution blocks 10 and the central mandrel 44.

[0025] The flow divider channels 24 are completely covered by the separator blocks 42 in Figures 6 and 7. The feed spirals 30 are not completely covered by virtue of a space between the separator blocks 42 and the front and rear faces 20 and 22 respectively adjacent the feed spirals 30 to define a melt outlet passage 46 extending into the extrusion passage 16. Melt will therefore overflow the edges of the feed spirals 30 to form a film of melt which is continuous about the circumference of the melt distribution block 10 at least leading into the extrusion passage 16.

[0026] In the arrangement illustrated, the front face 20 laps toward the rear face 22 adjacent the feed spirals 30 to provide the space for the melt outlet passage 46. Alternatively, the front face 20 and rear face 22 may be substantially parallel across the melt block 10 and the space for the melt outlet passage 46 may be accommodated by relieving the corresponding faces of the separator blocks 42.

[0027] Although two melt distribution blocks 10 are illustrated in the stacked array of the melt distribution die 40, it will be appreciated by those skilled in such structures that more or less melt distribution blocks may be accommodated depending on the number of layers required to be co-extruded.

[0028] Creating multi-layer films requires processing different materials and different layers. This means that dissimilar materials are processed at different temperatures. While not always the case, some materials can be damaged or degraded if they are exposed to temperatures above their respective optimal processing temperatures. When a temperature degradable material in a co-extrusion die is placed adjacent a material that

is processed at a higher temperature, as is often the case, the hotter processing material will transfer thermal energy to the heat sensitive material. This will tend to raise the temperature of the heat sensitive material and potentially cause its degradation.

[0029] According to a preferred embodiment of the present invention, the temperature transfer problem may be addressed by adding an insulation layer between adjacent melt distribution blocks 10 to inhibit thermal energy transferred between layers. Figure 8 illustrates one manner in which adjacent melt distribution blocks 10 may be thermally isolated. In the Figure 8 embodiment, one of the separator blocks, indicated by reference 60, includes an insulating zone 62. According to this embodiment, the insulating zone 62 may be a gap between adjacent faces 66 of adjacent parts 64 of the separator block 60. The gap 62 may be formed by machining at least one of the adjacent faces 66 of the parts 64 of the separator so as to form a recess extending into the face(s). In Figure 8, corresponding recesses extend into each adjacent face. It will be appreciated however that only one of the faces 66 need be provided with a recess to form the gap comprising the insulating zone 62.

[0030] In the Figure 8 embodiment, a spacer 68 is provided between the parts 64 of the spacer block 60 adjacent the mandril 44 to provide support and maintain the parts 64 in a spaced apart relationship. The gap which comprises the insulating zone 62 may extend between the parts 64 and a radially outward face 70 of the spacer 68. The spacer 68 may be of a metal, but preferably one with a lower thermal conductivity than that of the separator block 60.

[0031] Other approaches to thermal isolation may be used as alternative or in addition to the use of a gap for the insulation zone 62. For example, a ceramic insulator may be used between the parts 64 either within or in lieu of the gap.

[0032] The above description is intended in an illustrative rather than a restrictive sense. Variations to the exact structures described may be apparent to those skilled in co-extrusion dies without departing from the spirit and scope of the present invention as defined by the claims set out below.

[0033] Fig 9 is a plan view of a die-member 80. Groove-face-A is shown, having melt-conveying-channels-A. Groove-face-B lies on the opposite side of the die-member, i.e on the underside of the die-member in the view of Fig 9. The groove-face-B has melt-conveying-channels-B, which lie exactly underneath the melt-conveying-channels-A. That is to say, even if the die-member 80 were made of glass, the melt-conveying-channels-B would not be visible in the Fig 9 view, because they lie underneath the melt-conveying-channels-A.

[0034] The melt-conveying-channels-A in Fig 9 include: one entry-channel; two divider-grooves; four supply-grooves; eight feed-grooves;

four start-grooves; and four spiral-grooves.

[0035] Fig 10 shows a similar plan view of another die-member 82. Here, the whole set of melt-conveying-grooves-A as in Fig 9 is shown diagrammatically, in that the set shown in Fig 9 is represented by the line-A. In Fig 10, underneath the die-member 82, melt-conveying-grooves-B are represented by the line-B.

[0036] In Fig 10, the melt-conveying-grooves-A are staggered, i.e. circumferentially or orientationally offset, with respect to the melt-conveying-grooves-B. The line-A is spaced, in the circumferential or orientational sense, an arc-A relative to a datum-point 83 on the outer-face 84 of the die-member 82. The line-B lies spaced at an arc-B relative to the datum-point 83, which is different from arc-A.

[0037] When arc-A and arc-B are almost the same (Fig 10), the designer may find it convenient to arrange for both sets of melt-conveying-grooves-A and -B to be fed from a single point. So, in this case, melt-entry-channel-A 86 and melt-entry-channel-B 87 both open into a unitary melt-entry-port 89. A pipe-connector 90 enables the port 89 to be connected to a source of hot pressurised melt.

[0038] When arc-A and arcB differ greatly (Fig 11), preferably the melt-entry-port is in two sections, having separate pipe-connectors 92,93. In this case, the melt-entry-channel-A 94 is not in communication with the melt-entry-channel-B 95. The two separate pipe-connectors 92,93 may be connected, either both to the same source, or to two separate sources - which is appropriate, for example, if different melts are being fed respectively to the two sets of grooves.

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[0044] It is easier to ensure that the melt is divided evenly between the spiral-grooves if the number of spiral-grooves is a multiple of two, since then each junction is a simple T- or Y-junction. But, if the designer is bound to avoid the restriction to a multiple of two, an incoming-melt channel can be spilt into, say, three streams, rather than two, with careful engineering.

[0045] Fig 13 illustrates a measure that is aimed at ensuring evenness in the flow of melt to all the spiral-grooves. Fig 13 concerns the lands between the melt-conveying-grooves, and especially between the spiral-grooves. Two adjacent spiral-grooves, F and G, are shown. Spiral-land-FG is the land lying between spiral-groove-F and spiral-groove-G. The spiral-grooves-F and -G receive melt from start-groove-F and start-groove-G respectively. Base-land-FG is the land lying between start-groove-F on the left, start-groove-G on the right, spiral-groove-F to the inside, and feed-groove-FG-F and feed-groove-FG-G to the outside. (Feed-groove-FG-F and feed-groove-FG-G both receive melt from supply-groove-FG, as shown.) More precisely, the base-land-FG is bounded by the edges of the said grooves.

[0046] The groove-face of the illustrated die-member in Fig 13 is overlain by a smooth flat surface, for example by the smooth flat undersurface of another die-member stacked above the illustrated die-member. The spiral-land-FG is machined to lie well clear of this overlying surface; for example, the spiral-land-FG typically is a millimetre, or more, clear of the overlying surface. Thus, melt in the spiral-grooves spills over the edges of the spiral-grooves, as the melt passes inwards, towards the inner-edge of the illustrated groove-face.

[0047] It is recognised that, preferably, the melt should not be

allowed to spill over in the region of the base-land-FG. The base-land-FG should be clamped tightly against the said overlying surface: that is to say, the base-land-FG should not be clear of the overlying surface, such that melt from the feed-grooves-FG-F and -FG-G could spill over the base-land-FG, into the spiral-groove-F.

[0048] The function of the spiral-grooves is to ensure that the melt flows as evenly as possible over the inner-edge of the annular groove-face, i.e. that the flow over the inner-edge is the same at every point on the circumference of the inner-edge. This evenness-function might be compromised if the melt were allowed to flow over the base-land-FG (and, where there are four spiral-grooves, the corresponding three other base-lands), since the comparatively large area of the base-land would make it difficult to ensure that all the base-lands between the spiral-grooves allowed exactly equal amounts of melt to pass. By keeping the base-lands tight against the overlying surface, no melt can pass over any of the base-lands, whereby that source of possible unevenness is eliminated.

[0049] Evenness of melt flow over the inner-edge is very important to the quality of the finished plastic film, and designers of blown-film extrusion dies strive to ensure that the melt passing into and through the spiral grooves is the same for all the spiral-grooves.

[0050] Thus, the spiral-land-FG is machined away, and lies well below the level of the base-land-FG. This difference preferably is accommodated by providing a step-FG. The step-FG preferably is at least approximately contiguous with, and in line with, the left edge 98 of the start-groove-G. The step-FG, like the rest of the melt-conveying-channels of the die, should be profiled to avoid impeding the flow of melt, and especially to avoid even tiny pockets that might cause melt to slow down and hang up.

[0051] There are several kinds of channels or grooves included in the melt-conveying-channels-A as shown in Fig 9. On entering the die-member, the melt passes first through the flow-divider-grooves, where the incoming flow from the melt-entry-port is divided among four supply-grooves, into four separate streams. It might be considered that these four streams may be fed straight into the four spiral-grooves. However, it is recognised that this direct connection should be avoided. Liquid polythene, and many other plastics from which blown-film is made, have the unfortunate property that the viscosity of the liquid is very temperature-dependent. Even a slight cooling of the liquid causes a large increase in viscosity. In a melt-conveying-channel, the faster-moving liquid in the middle of the channel tends to be the less viscous liquid, i.e tends to be the hotter liquid, than the slow liquid adjacent to the walls of the channel. Thus, the cooler portions of the liquid flowing in the channels tend to migrate to the walls of the channels, the hotter portions to the centres. As a result, the channel can serve, indeed, almost as a temperature separator, separating the hot stream in the centre of the channel from the surrounding cooler stream on the walls.

[0052] Attention is directed to patent publication US-5,261,805 (Gates, Nov 1993). This patent shows the use of flow-mixing-channels to a centre-fed cylindrical die. Now, it is recognised that flow-mixing-grooves can be provided in an annular flat die, of the kind as shown herein, which is fed from a single melt-entry-port on the outer-face thereof. In the flow-mixing-grooves, the melt is subdivided and recombined, as it flows inwards towards the inner-edge of the die, and this can serve to even out some temperature differences.

[0053] The flow-mixing-grooves are interposed between the four supply-grooves and the four spiral-grooves, whereby the grooves convey

melt from the melt-entry-port in the outer-face inwards first through the flow-divider-channels to the supply-grooves, then inwards through the flow-mixing-channels-A, then inwards through the spiral-grooves-A, and finally inwards towards the inner-edge-A of the groove-face-A.

[0054] As shown in Fig 9, the flow-mixing-channels include subdivider-junctions and recombiner-junctions. At the subdivider-junctions, the four incoming-streams from the flow-divider-channels are sub-divided into respective left and right subdivided-streams. The recombiner-junctions lie inwards of the subdivider-junctions, and between adjacent subdivider-junctions, in the sense of being positioned to receive the subdivided-streams moving inwards from the adjacent subdivider-junctions.

[0055] Each recombiner-junction receives the left subdivided-stream from the adjacent one of the subdivider-junctions to the right of that recombiner-junction, and receives the right subdivided-stream from the adjacent one of the subdivider-junctions to the left of that recombiner-junction. The recombiner-junction combines the said left and right subdivided-streams into one recombined-stream respective to that recombiner-junction.

[0056] By this arrangement, the streams from the supply-grooves are split, the hot centre portions thereof going to one wall of the feed-grooves, and the cold outer portions going to the other wall of the feed-groove. When the portions recombine, in the start-grooves, the cold portions now lie to the inside, and the hot portions to the outside, of the start-grooves. As a result, the melt in the start-grooves, and hence in the spiral-grooves, tends to have a more even temperature profile than the melt in the supply-grooves.

[0057] The die-members shown in the previous drawings are flat. Alternatively, the melt-conveying-grooves may be provided on a convex conical surface, in the manner as illustrated, for example, in patent publication US-5,779,959 (Tuetsch, July 1998). Conical die-members may be provided in a stack, and the concave conical surface of one die-member serves as the overlying surface for the melt-conveying-grooves provided in the next die-member below, in the stack.

[0058] Many of the aspects of groove layout as described herein can be applied to conical dies. However, it can be difficult to machine grooves in a concave (i.e inwards-facing) surface, and therefore providing grooves only on the convex side of the die-member is preferred, when the die member is conical.